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Generic Requirements for ISDN Basic Access Digital Subscriber Lines

A Module of TSGR, TR-TSY-000440

Ex 10

This document replaces:

TR-TSY-000393, Issue 1, May 1988

For ordering information, see the references section.

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Note:
This document is a module of *Transport Systems Generic Requirements (TSGR)*, TR-TSY-000440.

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ISDN BASIC ACCESS DIGITAL SUBSCRIBER LINES

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Generic Requirements for
ISDN BASIC ACCESS
DIGITAL SUBSCRIBER LINES

LIST OF FIGURES

1. Introduction

1.1 Purpose

This Technical Reference (TR) presents Bellcore's view of proposed generic requirements for Digital Subscriber Line (DSL) transmission technology.

A Digital Subscriber Line is a technology that will allow digital access to customers over the present, in-place, two-wire loop plant. The driving force behind the development of DSLs is the need to provide "Basic Access" digital service to customers as part of Integrated Services Digital Network (ISDN), which will be an international standard for digital communications. The current telephone environment, including bridged taps and mixed wire gauge loops, intended for voice frequency transmission presents a complex environment for wideband transmission. Furthermore, requirements are necessary for new transmission equipment that accommodate ISDN Basic Access services and that protect the quality of old services.

The purpose of this Technical Reference is to present the generic technical requirements for DSLs that will operate in this environment. In Bellcore's view, these requirements must be satisfied in order to meet the typical needs of a Bell Operating Company.

1.2 Changes from Issue 1 of TR-TSY-000393

This Technical Reference supercedes its predecessor, Technical Reference, "ISDN Basic Access Digital Subscriber Lines", TR-TSY-000393[1]. The intention of reissuing TR-NWT-000393 is to clarify and to incorporate changes that were developed in T1E1.4 standard committee. Additional features/requirements were made. The most significant revisions are:

1. Added requirements for the LT jitter tolerance (Section 5.5.3) and LT jitter limitations (Section 5.5.4).
2. Removed requirements for message propagation delay (Section 5.6).
3. Added allocations for new M-channel bit functions (Section 5.7.4).
4. Provided activation at the U reference point without activation at the S/T reference points (Section 5.10).
5. Added requirements for the quiet mode and insertion loss test functions (Section 5.11).
6. Revised the dc metallic termination requirements (Section 6.2.3).
7. Revised longitudinal balance requirements for the NT (Section 6.2.5)
8. Added longitudinal balance requirements for the LT (Section 6.2.6).
9. Revised the procedure for NEXT calibration (Appendix C, Section C.1.1).
10. Revised the location for injecting longitudinal noise to the test loop (Appendix C, Section C.1.2).

Note: Change bars (¦) appear in the right-hand margin where significant changes or additions have been made to the text of Issue 1.

Significant deletions from the text of Issue 1 are marked by chevrons (>,<) in the margins.

1.3 Document Organization

The document is organized as follows:

Section 2 begins with an overview of Digital Subscriber Line systems, and discusses how DSLs fit into the loop architecture of a typical Bell Operating Company. In addition, Section 2 provides a brief description of other Technical References that reference this document, and which, together with this TR, provide a comprehensive description of the technical requirements for ISDN Basic Access transport.

Because DSLs must meet performance objectives while operating in the loop environment, Section 3 provides a brief description of the loop plant.

The DSL must also operate in the presence of other telecommunications systems; Section 4 describes the constraints imposed by crosstalk and noise, and states the requirements that DSLs must meet for electromagnetic compatibility.

Sections 1 to 4 are background information and contain no generic requirements.

Section 5 presents the detailed requirements for the transmitter and receiver portions of the DSL.

Section 6 contains the power and interface requirements for the DSL transmitters and receivers and the two-wire loop. Electrical protection, electrostatic discharge and electrical considerations are also contained in Section 6.

At the end of the document is a set of appendices that provide a glossary, statistics on loop transmission characteristics, a description of the required laboratory measurement of Bit Error Ratio (BER), and a set of fifteen loop make-ups that is used in that measurement.

1.4 Requirements Definition and Conventions

The requirements proposed in this Technical Reference adhere to the following definitions and conventions:

- Requirements
  - Requirements are features or functions that are mandatory, in Bellcore's view, for a BCC to realize the required operational compatibility or service consistency in the use of the product.

    The word "**shall**" identifies a proposed *requirement* and is flagged by the letter **(R)** in the left margin.
- Conditional Requirements
  - Conditional Requirements are features or functions that, in Bellcore's view, are necessary in specific BCC applications and may be reclassified as a requirement by a user, depending on the applications environment in which the system is deployed.

The word "**shall**" is also used to identify a *conditional requirement* and is flagged by the letter **(CR)** in the left margin.

- Objectives
  - — Objectives are features or functions that are desirable for a BCC's use and could be required by some BCCs. Objectives represent goals to be achieved in the telephone plant or criteria intended to enhance a product's image, performance or scope of application or operations. Objectives could be reclassified as requirements in the future.

    The word "**should**" identifies an *objective* and is flagged by the letter **(O)** in the left margin.
- The words "*to be provided*" are used to indicate that further requirements are expected to be included in future issues of this document.
- The words "*for further study*" are used to indicate that the possibility of further requirements being added to this document exists. However, it is not known at the time of publication whether additional requirements are needed.

2. DSL Overview and Related Technical References

2.1 Description of DSL Technology

A DSL provides high quality transmission capability for a single ISDN Basic Access customer over a non-loaded, two-wire metallic cable pair. The Basic Access signal consists of up to 144 kbit/s of bidirectional customer data ("2B+D"), plus one bidirectional channel of 16 kbit/s to support provisioning and maintenance operations (4 kbit/s M-channel), including performance monitoring, and framing and timing functions. This makes the total data rate of 160 kbit/s in each of the two directions of transmission.

The DSL consists of a master digital transmitter/receiver ("transceiver") and a slave digital transceiver, connected by a two-wire loop. Timing and control information are provided by the master to the slave. The DSL system uses the echo canceler with hybrid principle to provide full-duplex (i.e., simultaneous two-way) signal transmission over a two-wire non-loaded loop. The echo canceler technique is used to remove echoes of the transmitted signal that have mixed with the received signal; the echoes are reflections of the transmitted signal from discontinuities, such as bridge taps and gauge changes, or from line impedance mismatches and transformer hybrid leakage. This permits a relatively weak received signal to be accurately detected and is the means for avoiding the use of a separate pair of wires for each direction of transmission. A quaternary line code is employed. Once each is locally powered and joined by a two-wire loop, the pair of transceivers automatically, and without field adjustment, establish Open Systems Interconnection (OSI) Layer 1 communication.

2.2 DSL Transmission and System Interfaces

To form a viable transmission system, the digital transceivers are embedded in equipment which provides for functions such as powering and network operations support, and incorporates external electrical interfaces. In CCITT terminology, the master transceiver is located in the "line termination" (LT) and the slave transceiver is located in the "network termination" (NT). Typically the LT refers to equipment that terminates the access line at the network end and is located in and interfaces with a network element, such as a local switching system or carrier terminal. The general term NT is used to refer to the network termination function whether it is in an NT1, NT2, or other equipment, as shown in Figure 2-1. The NT is used to refer to equipment that terminates the DSL on the customer side of the interface as shown in Figure 2-1.

Also shown in Figure 2-1 is the location of the interface of the access line with the NT that is commonly called the "U" interface point. The location of the interface described in this TR shall be on the customer's premises at the connector terminals of the NT equipment. The interface described here is not necessarily the same as the "network interface" (NI) which is also on the customer's premises and subject to rules, if any, established by appropriate regulatory bodies.

The electrical interfaces associated with the LT/NT transmission system are of particular interest and are also illustrated in Figure 2-1. A standard electrical interface has been internationally established by the International Telegraph and Telephone Consultative Committee (CCITT)[2] at the "T" reference point, under the assumption that the carrier also provides the NT. The "T" reference point is a four-wire interface, intended for inside wiring, which supports the ISDN Basic Access service capability and is independent of the transmission scheme chosen for the two-wire loop.

In this TR, a network interface is assumed to be at the network side of the NT, regardless of the provider of the customer premises equipment. This interface will permit independent supply of NT and LT equipment. Based on this assumption, it is necessary to fully describe the DSL technology employed for loop transmission.

Bellcore Technical Reference, "ISDN Basic Access Transport System Requirements," TR-NWT-000397,[3] sets forth proposed generic system requirements for the LT and NTs. These requirements include provision for "sealing current" on the two-wire loop, in-service digital error performance monitoring, metallic and digital testing features, an embedded operations channel for LT-to-NT communications, and communications interfaces to operations systems. Where absolutely necessary, certain requirements found in TR-NWT-000397[3] are duplicated in this TR.

The quality of service delivered in Basic Access may be expressed in terms of statistics of errors on the customer's B or D channels. Some examples of grouping of digital errors for purposes of defining performance are errored seconds, severely-errored seconds, unavailable seconds, and out-of-frames. The use of such performance statistics in characterizing systems embedding DSLs is discussed in TR-NWT-000397[3]. Objective requirements for bit error ratio of a DSL under laboratory conditions are given in Appendix C of this TR.

2.3 Transport Systems Embedding DSLs

Figure 2-2 illustrates the various network transport systems for ISDN Basic Access which may embed DSLs. In addition to the simple system consisting of an LT, a two-wire loop, and an NT, a repeater may be employed on the customer side of the NT. (At present, DSL repeaters are not expected to be applied within the telephone company network; however, ISDN technology plans do not preclude them.) Digital Loop Carrier (DLC) systems are relied upon to extend the range of the simple DSL from the serving central office (CO), and digital interoffice carrier systems are utilized to extend ISDN switching capability from remote COs to the serving CO.

Carrier systems play an important role in ISDN Basic Access transport. As shown in Figure 2-2, loop and interoffice carrier can each be employed in either "universal" or "integrated" arrangements. (Note that universal carrier arrangements employ *two* DSLs for each Basic Access subscriber.) Bellcore TR-NWT-000397[3] contains the ISDN feature requirements for all types of carrier systems and for all carrier system line units which embed DSLs. Carrier system requirements include specification of the multiplexing scheme for Basic Access circuits on 1.544 Mbps facilities.

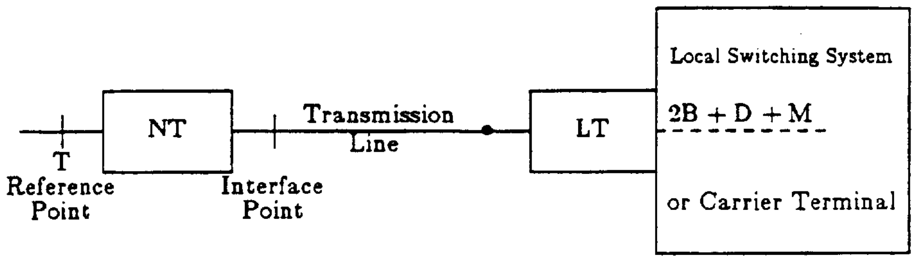
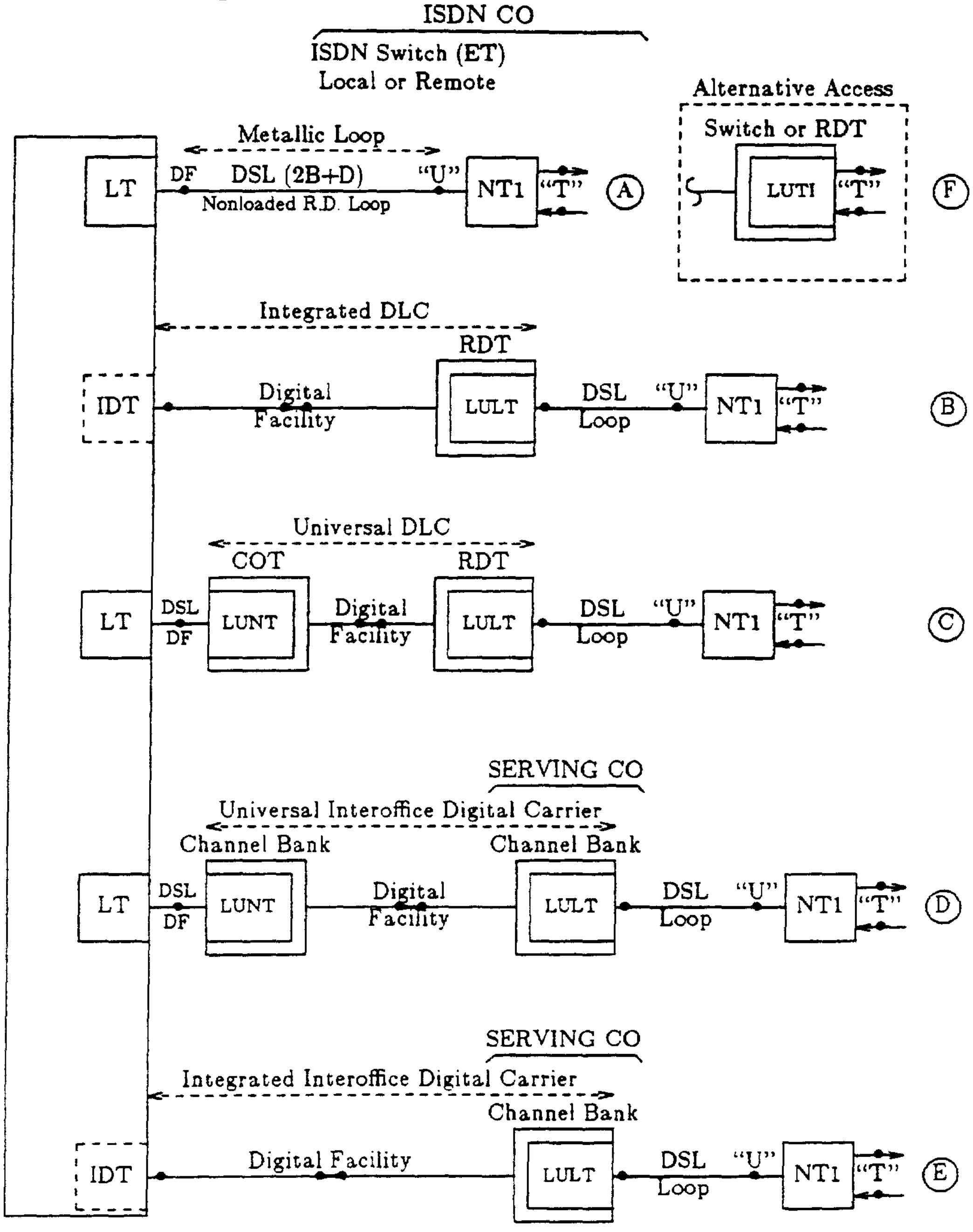


Figure 2-1
Access Reference Configuration

Figure 2-2: Architectures for ISDN Basic Access



LEGEND:

COT = Central Office Terminal	IDT = Integrated Digital Terminal	NT1 = Network Termination 1
DF = Distribution Frame	LT = Line Termination	R.D. = Resistance Design
DLC = Digital Loop Carrier	LULT = Line Unit "LT"	RDT = Remote Digital Terminal
DSL = Digital Subscriber Line	LUNT = Line Unit "NT1"	"T" = T Reference Point
ET = Exchange Termination	LUTI = Line Unit "T Interface"	"U" = U Reference Point

3. Loop Plant Environment

To provide economic access, DSL performance objectives include: 1) transceivers operate over two-wire twisted metallic cable pairs that were originally installed for voice frequency transmission, 2) it is not necessary to use plant conditioning or pair selection but only non-loaded loops meeting resistance design requirements may be used, and 3) the transceivers achieve spectrum compatibility with existing transmission systems. The loop transmission facilities of the Bell Operating Companies include aerial, buried and underground cables, with a multiplicity of wire gauges, pair counts, splices and bridged taps. The DSL must be designed to operate over a vast range of loops, with transmission characteristics that vary widely. It is impossible to specify the transmission parameters of each loop to which a given DSL may be connected. The most recent survey of loop transmission characteristics was performed in 1983. Transmission characteristics for 100 representative loops, selected from the 2290 loops surveyed, are available on diskettes from Bellcore as the I-MATCH.1 Loop Characterization Data Base[4]. A summary of the results of that survey may be found in Appendix B of this document. A complete report on the 1983 survey, with extensive statistical abstracts of the loop transmission parameters, may be found in Science and Technology report ST-TSY-000041[5].

Various simulation studies conducted at Bellcore used the 1983 Loop Survey data as their source to evaluate the feasibility of high speed data transmission over the existing telephone plant. A set of fifteen loop make-ups obtained based on the survey is used as a bench mark test for performance measurements (Appendix D).

4. Spectrum Management

The current structure of the telecommunications industry has evolved into a wide range of diversity of products and systems being used in the field. For this reason, it is essential to insure old and new services are compatible. This section provides the constraints on DSL operation to insure that interference caused by DSLs will not effect other systems in the same cable while maintaining the quality of DSL services.

4.1 Crosstalk

It is a general goal that DSL systems will coexist with other transmission systems in the telephone plant. In order to achieve this, energy that couples into a DSL via the two-wire loop must not result in unacceptable degradation of the DSL's operation, and energy that originates in the DSL must not couple into other systems in a manner that degrades their operation.

Near-end crosstalk (NEXT) between pairs in the same cable is the dominant source of degradation of DSL system performance. NEXT interference exceeds that due to far-end crosstalk (FEXT). NEXT coupling in telephone cables increases as a function of frequency at about 15 dB per decade of frequency at frequencies above 20 kHz and in the band used by the DSL (The model is accurate to at least 1 MHz).

The level of interference due to NEXT, is a function of the loop length, cable geometry, the waveform of the transmitted signals, and spectral characteristics of the systems involved as well as receiver characteristics. As loop length and cable geometry cannot be controlled by the DSL designer, the only parameters available to manage crosstalk are those determined by the receiver filter, the transmitted signal waveforms, and the spectrum of the transmitted line code.

There are two main attributes of the line code that affect the NEXT performance: the insertion loss of the loop and the crosstalk that is caused by the other transmitters in the same cable transmitting the same line code. To a large extent, both of these attributes are related to the bandwidth and the power spectral density of the line code. The selected 2B1Q line code (Section 5.2) has a slight advantage over other line codes since its baud rate is substantially less than that of other line codes. The baud rate for the 2B1Q line code is 80 kbaud for 160 kbit/s transmission. Further information on crosstalk and spectrum management may be found in References [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16]

The constraints on DSL operation imposed by crosstalk requirements by the line signal specified in Section 5.2 may be derived with the aid of the NEXT insertion loss model in Figure 4-1. The model was derived from computer simulations and measurements of crosstalk in cable pairs. It gives, at each frequency, the 1% point on the distribution of NEXT from 49 common binder group disturbers. This is nearly the most severe NEXT condition that would exist. The model is meant to be valid under the following conservative conditions:

a. The disturbing transmitters use the same binder group of the cable as the disturbed system;

b. the disturbing transmitters are co-located with the disturbed receiver (either end);

c. the termination impedances are matched to the characteristic impedance of the cable pairs at each frequency;

d. the loop configurations contain no bridged taps or gauge changes; and

e. the loops are long (i.e., the crosstalk statistics apply to infinite length loops).

Note that a simplified model is used as a basis of laboratory measurements described in Appendix C.

4.2 Electromagnetic Emission and Immunity Requirements and Objectives

As described in Section 2, Digital Subscriber Line transmitters and receivers are embedded in other equipment. In general, this equipment must meet electromagnetic emission and immunity requirements and objectives, as specified in FCC and Bellcore documents. Details may be found in TR-NWT-000397[3].

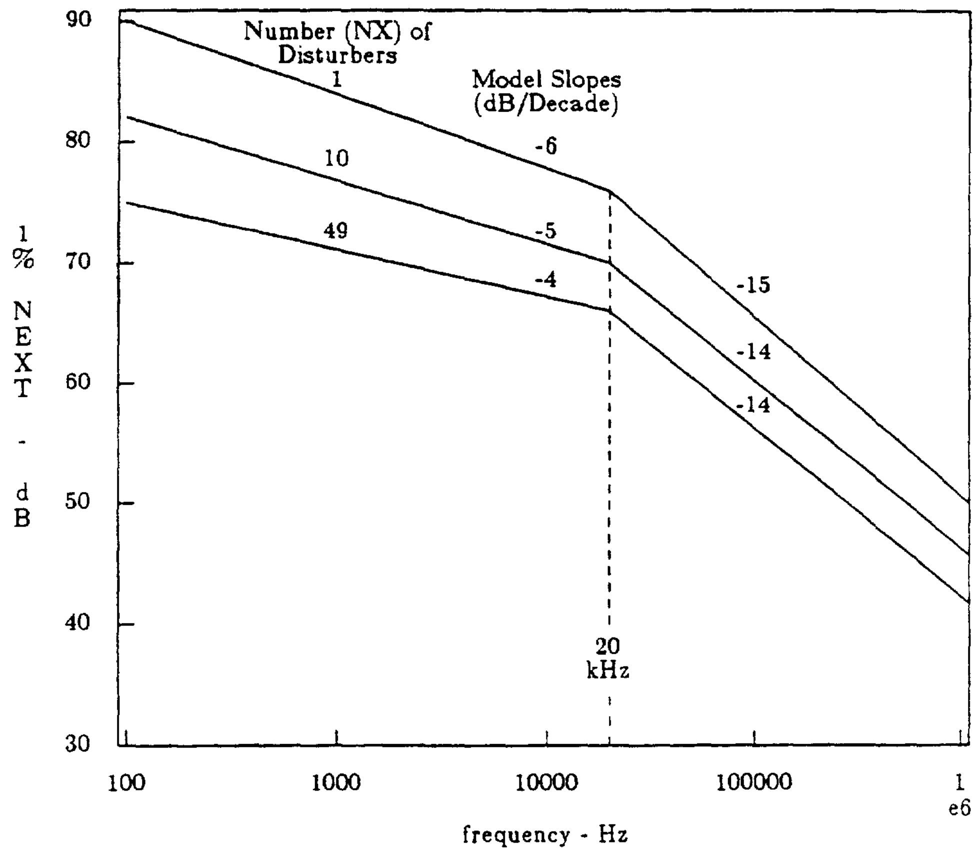


Figure 4-1 Models of 1% NEXT for 18 kFt of 22GA PIC, Terminated With The Characteristic Impedance Z_o of Cable at Each Frequency. NEXT Disturbers In Same Cable Binder Unit of 50 pairs

5. Transmission Characteristics

This section states the proposed generic requirements for the transmission characteristics of the DSL.

5.1 Transmission Method

The transmission system uses the echo canceler with hybrid (ECH) principle to provide full-duplex operation over a two-wire subscriber loop. The echo canceler produces an approximate replica of the echo of the near end transmission, which is then subtracted from the total received signal.

The system is intended for service on non-loaded twisted pair cables of up to 18 kFt and meeting 1300 Ohms resistance design, or about 42 dB loss at 40 kHz.

5.2 Line Code

(R) The line code **shall** be 2B1Q (2 Binary, 1 Quaternary). This is a 4-level pulse amplitude modulation (PAM) code without redundancy.

(R) The user-data bit stream, comprised of two 64-kbit/s B channels and a 16-kbit/s D channel, entering the NT from the S/T interface (i.e., entering the S/T interface toward the NT) and the equivalent bit stream on the LT-side **shall** be grouped into pairs of digits (bit fields) for conversion to quaternary symbols that in the sequel are also called quats. In each pair of bits so formed, the first bit is called the sign bit and the second is called the magnitude bit. Figure 5-1 shows the relationship of the bits in the B and D channels to quats. The B- and D-channel bits are scrambled before coding. M-channel bits (M_1 through M_6), for maintenance and other purposes, are also paired, scrambled, and coded in the same way (see Sections 5.7.3 and 5.7.4 for more details on M-channel bit assignments).

Each successive pair of scrambled bits in the binary data stream is converted to a quaternary symbol to be output from the transmitter at the interface, as specified below:

First Bit (Sign)	Second Bit (Magnitude)	Quaternary Symbol (Quat)
1	0	+3
1	1	+1
0	1	−1
0	0	−3

The four values listed under "Quaternary Symbol" in the table are to be understood as symbol names, not numerical values.

At the receiver, each quaternary symbol is converted to a pair of bits by reversing the table above, descrambled, and finally formed into a bit stream(s) representing B and D channels, and M-channel bits. The bits in the B and D channels are properly placed by reversing the relationship in Figure 5-1.

5.2.1 Characteristics of Pulses

Individual pulses, as observed at the network termination of the DSL, **shall** have the following characteristics:

5.2.1.1 Transmitted Pulses

(R) The transmitted pulse **shall** have shape and normalized (relative to peak) magnitude as specified in Figure 5-2.

(R) The pulse mask for each of the four quaternary symbols **shall** be obtained by multiplying the normalized pulse mask shown in Figure 5-2 by 2.5 Volts, 5/6 Volts, -5/6 Volts or -2.5 Volts.

Note: It is recognized that for an interim period, until 1992, certain implementations may not be able to meet the 2.5 Volts nominal pulse amplitude requirement. During this period of time, nominal pulse amplitudes between 2.5 Volts and 2.0 Volts will be acceptable.

(R) For measurement reference purposes, the termination impedance **shall** be 135 Ohms resistive over a frequency band of 0 Hz to 160 kHz.

5.2.1.2 Received Pulses

(R) When the pulses described above are transmitted over the telephone plant, the DSL receiver **shall** receive any random sequence of these pulses with a Bit Error Ratio (BER) of less than 10^{-7}. Appendix C describes a test procedure for determining conformance with this requirement.

(R) For purposes of testing, the telephone plant is defined as a set of fifteen loops presented in Appendix D of this Technical Reference. In addition, the DSL **shall** operate with the BER defined above on a "zero-length" loop, i.e. with the LT connected to the NT through a pair of wires of length no greater than 10 feet (3 meters).

5.2.2 Power Spectrum of the Transmitted Signal

5.2.2.1 Power Spectral Density

(R) The upper bound of the average power spectral density of the signal transmitted by the DSL transmitter **shall** be as shown in Figure 5-3. Measurements to verify compliance with this requirement are to use a noise power bandwidth of 1 kHz.

5.2.2.2 Total Power

(R) The average power of a signal consisting of a framed sequence of symbols with a synchronization word and equiprobable symbols at all other positions **shall** be between 13.0 dBm and 14.0 dBm over the frequency band from 0 Hz to 80 kHz. The nominal peak of the largest pulse **shall** be 2.5 Volts.

Note: Consistent with 5.2.1.1, during an interim period, until 1992, a corresponding reduction in transmitted power (i.e., with a nominal pulse peak of 2.0 Volts the average power **shall** be between 11.1 and 12.1 dBm) will be acceptable.

5.3 Baud Rate

(R) The baud rate from the LT **shall** be 80 kbaud ±5 ppm.

5.4 Timing

(R) The digital subscriber line **shall** operate in a master-slave mode with the NT slaved to the signal received from the LT; that is, the signals transmitted from the NT toward the LT **shall** be synchronized to a clock that is synchronized to the received signal. Should the NT receiver lose "loop timing", it **shall** be capable of accepting timing input from an oscillator located in the NT. When the signal transmitted from the NT is not synchronized to the signal received from the LT, the NT oscillator **shall** have the accuracy of a Stratum 4 clock (i.e., ±32 ppm).

5.5 Jitter

In this TR, jitter is specified in terms of unit intervals (UI) of the nominal 80 kbaud signal (12.5 μs).

5.5.1 NT Input Signal Jitter Tolerance

(R) The NT **shall** meet the performance objectives specified in Section 5.2.1.2 and Appendix C, with wander/jitter at the maximum magnitude indicated in Figure 5-4, for single jitter frequencies in the range of 0.1 Hz to 20 kHz, superimposed on the test signal source with the received signal baud rate in the range of 80 kbauds ±5ppm. The NT **shall** also meet the performance objectives with wander per day of up to 1.44 UI peak-to-peak where the maximum rate of change of phase is 0.06 UI/hour.

5.5.2 NT Output Jitter Limitation

With the wander/jitter as specified above, except as noted, superimposed on the NT input signal, the jitter on the transmitted signal of the NT towards the LT **shall** conform to the following, with the received signal baud rate in the range of 80 kbaud ±5 ppm, as described in 5.3:

(R) The jitter **shall** be equal to or less than 0.04 UI peak-to-peak and less than 0.01 UI rms when measured with a high-pass filter having a 6 dB/octave roll-off below 80 Hz.

(R) The jitter in the phase of the output signal (the signal transmitted toward the LT) relative to the phase of the input signal (from the LT) **shall** not exceed 0.05 UI peak-to-peak and 0.015 UI rms when measured with a band-pass filter having 6 dB/octave roll-offs above 40 Hz and below 1.0 Hz. (Note that 1.0 Hz cut-off assures that the average difference in the phase of the input and output signals is subtracted.) This requirement applies with superimposed jitter in the phase of the input signal as specified in 5.5.1 for single frequencies up to 19 Hz.

(R) The maximum (peak) departure of the phase of the output signal from its nominal difference (long-term average) from the phase of the input signal (from the LT) **shall** not exceed 0.1 UI. This requirement applies during normal operation including following a "warm start". (Note that this means that, if deactivated and subsequently activated in conformance with the "warm start" requirements, the long-term average difference in phase of the output signal from the phase of the input signal **shall** be essentially unchanged.)

5.5.3 LT Input Signal Jitter Tolerance

(R) The LT **shall** meet the performance objectives specified in Section 5.2.1.2 and Appendix C, with input signal (i.e., signal originating from the NT) jitter as specified in 5.5.2.

5.5.4 LT Output Jitter Limitation

(R) The jitter on the transmitted signal of the LT towards the NT **shall** be as indicated in Figure 5-4 for single jitter frequencies in the range of 0.1 Hz to 20 kHz.

5.6 Message Propagation Delay

Requirements for message propagation delay may be found in TR-NWT-000397[3].

5.7 Frame Structure

(R) The information flow across the interface point **shall** utilize frames and superframes as shown in Figures 5-5 and 5-6.

(R) As shown in Figure 5-5, a frame **shall** be 120 quaternary symbols. The nominal time for a frame is 1.5 msec.

5.7.1 Synchronization Word

(R) The first nine symbols of the frame **shall** be a synchronization word (SW), with the quaternary symbols in the following sequence, except as noted in 5.7.4:

$$SW = +3\ +3\ -3\ -3\ -3\ +3\ -3\ +3\ +3$$

5.7.2 User Data (2B+D)

(R) Following the synchronization word, the next 108 quaternary symbols in the frame **shall** be organized as shown in Figure 5-5 (nine-symbol (18-bit) field repeated twelve times). Except during start-up, the channels **shall** be transparent to user data bits.

Note: No idle code is specified across the interface. However, when one or more B or D channels are not in use in either direction, the time slots allocated to the channel(s) contain idle code specified in ANSI T1.605-1989. This idle code is generated external to the interface.

(R) Access to transmitted and received customer information (B and D channels) in the LT **shall** be provided as specified in TR-NWT-000397[3].

5.7.3 M Channel

(R) The last six bits (M_1 through M_6), **shall** be paired, scrambled, and coded to quaternary symbols (3 symbols). These bits form a 4 kbit/s M channel for maintenance and other purposes (see Figure 5-6).

5.7.4 Superframes

(R) Frames **shall** be organized into superframes, as shown in Figure 5-6. Eight frames (12 msec) **shall** constitute a superframe. The first frame in the superframe **shall** be identified by inverting the polarity of Synchronization Word (SW) in this frame. The Inverted Synchronization Word is abbreviated ISW:

$$ISW = -3\ -3\ +3\ +3\ +3\ -3\ +3\ -3\ -3$$

The first frame in the superframe of the signal transmitted from the NT **shall** be the next frame following the first frame in the superframe of the signal received from the LT. See 5.7.5, and Figure 5-8 for specific alignment of transmitted and received frames.

(R) The 48 M bits in the superframe **shall** be assigned as follows:

- 24 bits--Embedded operations channel (eoc), both directions
- 12 bits--Cyclic Redundancy Check (crc), both directions
- 1 bit--Start-up (act)[1] , both directions
- 1 bit--Far end block error (febe), both directions
- 1 bit--Turn-off (dea)[2] , LT to NT
- 2 bits--Power status of NT ($ps_{1,2}$), NT to LT
- 1 bit--NT in Test Mode (ntm), NT to LT
- 1 bit--Cold-start-only (cso), NT to LT
- 1 bit--U-Interface-Only-Activation (uoa)[3] , LT to NT
- 1 bit--S/T-Interface-Activity-Indicator (sai)[3], NT to LT
- 1 bit--Alarm Indication Bit (aib)[3], LT to NT
- 1 bit--Network Indicator Bit (1^*)[3], (NT to LT, reserved for network use)
- 4 bits--Reserved, set equal to binary 1, NT to LT
- 7 bits--Reserved, set equal to binary 1, LT to NT

A brief description of the M-channel bit functions is given below.

5.7.4.1 Embedded Operations Channel (eoc)

(R) Twenty-four bits per superframe (2 kbit/s) **shall** be allocated to an embedded operations channel. The eoc bits are the M_1 through M_3 in all

1. Previously called activation bit.
2. Previously called deactivation bit.
3. Previously a bit reserved for future standardization.

eight frames of the superframe (Figures 5-6a and 5-6b). The eoc bits are used to support operations communications needs between the LT and the NT. Further information on eoc may by found in TR-NWT-000397[3].

5.7.4.2 Cyclic Redundancy Check (crc)

(R) Twelve bits per superframe (1 kbit/s) **shall** be allocated to the cyclic redundancy check (crc) function. The crc bits are the M_5 and M_6 bits in frames 3 through 8 of the superframes (Figures 5-6a and 5-6b). The crc is an error detection code that **shall** be generated from the appropriate bits in the superframe and inserted into the bit stream by the transmitter. At the receiver, a crc calculated from the same bits **shall** be compared with the crc value transmitted in the bit stream. If the two crcs differ, there has been at least one error in the covered bits in the superframe.

5.7.4.2.1 crc Algorithms:

(R) The cyclic redundancy check (crc) code **shall** be computed using the polynomial:

$$P(x) = x^{12} \oplus x^{11} \oplus x^3 \oplus x^2 \oplus x \oplus 1$$

where

$\oplus$ = modulo 2 summation.

One method of generating the crc code for a given superframe is illustrated in Figure 5-7. At the beginning of a superframe all register cells are cleared. The superframe bits to be crc'd are then clocked into the generator from the left. During bits which are not covered by the crc (SW, ISW, M_1, M_2, M_3, M_5, M_6) the state of the crc generator is frozen and no change in state of any of the stages takes place. After the last superframe bit to be crc'd is clocked into REGISTER CELL 1, the twelve register cells contain the crc code of the next superframe. Between this point and the beginning of the next superframe, the register cell contents are stored for transmission in the crc field of the next superframe. Notice that superframe bit CRC1 resides in REGISTER CELL 12, CRC2 in REGISTER CELL 11, etc.

Other viable methods for generating the crc bits exist. In the case that a method other than the one presented is used, the CRC1 must correspond to the most significant bit of the crc remainder, the CRC2 to the next most significant bit, etc. The block diagram presented is intended to clarify the definition of the crc superframe bits. Other implementations are possible.

Note: The binary 1s and 0s from the S/T interface, and corresponding bits from the LT, must be treated as binary 1s and 0s, respectively, for the computation of the crc.

5.7.4.2.2 Bits covered by the crc

(R) The crc bits **shall** be calculated from the bits in the D channel, both B channels, and the M_4 bits.

5.7.4.3 The act Bit

(R) The start-up (act) bit is the M_4 bit in the first basic frame of superframes transmitted by either transceiver (Figure 5-6a and 5-6b). The act bit is set to binary one (1) as a part of the start-up sequence to communicate readiness for layer 2 communication.

5.7.4.4 Far End Block Error (febe)

(R) The Far End Block Error (febe) bits are the M_6 bits in the second basic frame of superframes transmitted by either transceiver (Figures 5-6a and 5-6b). As crc errors are detected at the receiver, a febe bit **shall** be generated. The febe bit **shall** be set to binary one (1) if there are no errors in the superframe and binary zero (0) if the superframe contains an error. The febe bit **shall** be placed in the next available outgoing superframe and transmitted back to the originator. The febe bits in each direction of transmission may be monitored to determine the performance of the far end receiver.

5.7.4.5 The dea Bit

(R) The turn-off (dea) bit is the M_4 bit in the second basic frame of superframes transmitted from the LT (Figure 5-6a). The dea bit is set to binary zero (0) by the LT to communicate to the NT its intention to turn-off.

5.7.4.6 NT Power Status Bits (ps_1, ps_2)

(R) The power status bits (ps_1, ps_2) are the M_4 bits in the second and third basic frames of superframes transmitted by the NT (Figure 5-6b). The power status bits **shall** be used to indicate NT power status. Table 5-1 shows the power status bit assignments and the corresponding messages and definitions.

These bits are set and held constant until the power status of the NT changes. It is expected that primary power will be provided by the normal AC mains. Secondary power (if provided) would typically be provided via a backup battery at the customer location.

(R) The NT **shall** have sufficient energy storage to transmit the dying gasp indication for a minimum of three superframes.

Table 5-1
Power Status Bit Assignments and Messages

NT Status	ps_1 ps_2 Binary Values	Definition
All Power Normal	11	Primary and Secondary power supplies are both normal.
Secondary Power Out	10	Primary power is normal, but the Secondary power is marginal, unavailable, or not provided.
Primary Power Out	01	Primary power is marginal or unavailable, Secondary power is normal.
Dying Gasp	00	Both Primary and Secondary power are marginal or unavailable. The NT may shortly cease normal operation.

5.7.4.7 NT Test Mode Indicator Bit (ntm)

(R) The NT test mode indicator (ntm) bit is the M_4 bit in the fourth basic frame of superframes transmitted by the NT (Figure 5-6b). The ntm bit **shall** be used to indicate that the NT is in a customer-initiated test mode. The NT is considered to be in a test mode when the D channel or either one of the B channels are involved in a customer locally-initiated maintenance action. While in test mode, the NT may be unavailable for service or the NT may be unable to perform actions requested by eoc messages. The bit **shall** be a binary one (1) to indicate normal operation and binary zero (0) to indicate test mode. While indicating test mode (binary zero (0)), this bit is held constant until the test mode status of the NT changes. The return to binary one (ntm = 1) indicates the return to normal mode.

5.7.4.8 Cold-Start-Only Bit (cso)

(R) The cso bit is the M_4 bit in the fifth basic frame of the superframes transmitted by an NT (Figure 5-6b). It **shall** be used to indicate the start-up capabilities of the NT transceiver. If the NT has a cold-start-only transceiver, this bit is set to binary one (1). Otherwise, this bit **shall** be set to binary zero (0) in SN3.

5.7.4.9 U-Interface-Only-Activation (uoa)

(R) The uoa bit is the M_4 bit in the seventh basic frame of the superframes transmitted by an LT. It **shall** be used to request the NT to activate or deactivate the S/T interface (if present). If the S/T interface is to be activated, this bit **shall** be set to binary one (1). Otherwise, this bit **shall** be set to binary zero (0).

5.7.4.10 S/T-Interface-Activity-Indicator (sai)

(R) The sai bit is the M_4 bit in the seventh basic frame of the superframes transmitted by an NT. It **shall** be used to indicate to the LT when there is activity (INFO 1 or INFO 3) at the S/T reference point. If there is activity at the S/T reference point, this bit **shall** be set to binary one (1). Otherwise, this bit **shall** be set to binary zero (0).

5.7.4.11 Alarm Indication Bit (aib)

(R) This aib bit is the M_4 bit in the eighth basic frame of the superframes transmitted toward the NT. When the transmission path for the D, B_1, and B_2 channels has been established all the way to the local exchange, a binary one (aib = 1) **shall** be forwarded to the NT. Failure or interruption of an intermediate transmission system which transports the D, B_1, or B_2 channels **shall** result in forwarding binary zero (aib = 0) to the NT. Such failures may include loss of signal, loss of frame synchronization (carrier link or basic access DSL), and transmission terminal failure. Intermediate transmission interruptions may include loopbacks at intermediate points or the absence of provisioning of an intermediate transmission system.

5.7.4.12 Network Indicator Bit for Network Use (1)*

(R) The network indicator bit, the M_4 bit in the eighth basic frame of superframes transmitted toward the network, is reserved for network use. The NT **shall** always set this bit to binary one (1) toward the network.

5.7.4.13 Reserved Bits

(R) All bits in M_4, M_5, and M_6 not otherwise assigned are reserved for future standardization. Reserved bits **shall** be set to binary one (1) before scrambling.

5.7.5 Frame Offset

(R) Received and transmitted frames at the NT **shall** be offset by 60±2 quaternary symbols (i.e. about 0.75 msec), as shown in Figure 5-8.

5.8 Scrambling Method

(R) The user data channel bits and the M-channel bits in each direction **shall** be scrambled with a 23rd-order polynomial (see Figure 5-9) prior to coding and the insertion of SW/ISW.

(R) In the NT-to-LT direction the polynomial **shall** be

$$x^{-23} \oplus x^{-18} \oplus 1$$

where

$\oplus$ = modulo 2 summation

(R) In the LT-to-NT direction the polynomial **shall** be

$$x^{-23} \oplus x^{-5} \oplus 1$$

where

$\oplus$ = modulo 2 summation

(R) The binary data stream **shall** be recovered in the receiver by applying the same polynomial to the scrambled data as was used in the transmitter.

5.9 Transmitter Linearity

(R) The pulses at the transmitter output of either the NT or the LT, corresponding to the symbol names +3, +1, −1 and −3 **shall** nominally all have the same shape and have the ratio 3 : 1 : −1 : −3. Impairment resulting from deviations from this ratio is called nonlinearity. This nonlinearity is defined as the residual after subtracting a perfectly linear signal (a linearity standard) from the transmitter output line signal. The linear signal is constructed from the same random data that is input to the transmitter and processed through a linear filter. The parameters of the linear filter are first optimized to reduce the residual to a minimum. The linearity **shall** be determined by means of a laboratory test:

The transmitter is connected as shown in Figure 5-10; that is, terminated in a 135 Ohm resistance through a zero-length loop, and driven by an arbitrary binary sequence. The voltage appearing across the resistance **shall** be filtered (anti-alias), sampled and converted to digital form (V_{out}) with a precision of no less than 12 bits. These samples **shall** be compared (subtractor) with the output of an adjustable, linear filter. the input of which is the scrambled, framed, and linearly encoded transmitter input. The linear digital filter input ("Quaternary Input Data" in Figure 5-10) is considered a linearity standard. It is produced from the transmitter output by an errorless receiver (with no descrambler), or from the scrambled transmitter input data if it is available. If the samples input to the adjustable filter are available in digital form, no additional A/D converter is required. Whether analog or digital, these samples **shall** be in the ratio 3 : 1 : −1 : −3, to an accuracy of at least 12 bits.

(O) The sampling rate of the samplers and filters **should** be several times the baud rate for good accuracy. Alternatively, the sample rate may be at the baud rate, but the rms values are obtained by averaging over all sample phases relative to the transmitter signal.
Because the anti-alias filter, sampler, and A/D converter operating on the transmitter output may introduce a loss or gain, proper calibration requires determining $<V_{out}^2>$ at the filter output, as shown in Figure 5-10, rather than the mean-squared value of the transmitter output itself.

(R) The transmitted and received signals **shall** have sufficient linearity so that the residual rms signal is at least 36 dB below the signal $<V_{out}^2>$. This requirement applies under all normal transceiver conditions and over the prescribed range of sealing current (See 6.2.2).

5.10 Start-Up Procedure

The master-slave mode described in 5.4, does not apply immediately after connecting the transmission line to the NT and/or turning on its power. This happens at the time of installation, following power failures, or after temporarily disconnecting the NT or temporarily switching off its power. In these situations, the LT may begin a start-up sequence in order to achieve the master-slave mode. The NT is responsible for initiating the start-up sequence upon power-up or upon a request for start-up from the customer terminal equipment (TE).
Also, for NTs that have the optional warm-start capability (see Section 5.10.1.4), master-slave mode does not apply until start-up has been requested and synchronization achieved.
While the system is not in master-slave mode, that is, during the start-up sequence or while in the RESET or RECEIVE RESET state, the transmission is not transparent to user data (B_1-, B_2-, or D- channel bits); the signals that are present at the interface are generated by the LT and the NT transceivers.

5.10.1 Definition

The following definitions are for the purpose of clarifying requirements that are to follow.

5.10.1.1 Start-Up

Start-up is a process characterized by a sequence of signals produced by the LT and the NT. Start-up results in establishment of the master-slave mode, i.e., synchronization of the receivers and the training of equalizers (if used) and echo cancelers to the point that two-way transmission requirements are met.

5.10.1.2 Total Activation

The word total activation is used in this TR to describe a process that includes the start-up process as described here for this interface and activation of the S/T interface as described in T1.605-1989.

5.10.1.3 Cold-Start-Only

The requirements in this TR focus primarily on cold-start-only NTs (see Sections 5.7.4.8 and 5.10.2).

5.10.1.4 Warm Start

The start-up process that applies to transceivers meeting the start-up time requirements for the warm-start option (see Section 5.10.7.7) after they have once been synchronized and have subsequently responded to a turn-off announcement. Warm start applies only if there have been no changes in line characteristics and equipment. Transceivers that meet warm-start requirements are called warm-start transceivers.

Note: As indicated in 5.10.1.3, the requirements in this TR focus primarily on cold-start-only NTs. However, transceivers meeting the optional warm-start capability may be used without harm.

5.10.1.5 Cold Start

The start-up process that applies to transceivers that either do not meet start-up time requirements for the warm-start option (see Section 5.10.7.7), or have not been continuously in a RESET state that resulted from a turn-off request to the NT. Cold start also applies if there have been changes in line characteristics or equipment or both. A cold start should always start from the RESET state.

Note: As indicated in 5.10.1.3, the requirements in this TR focus primarily on cold-start-only NTs. However, transceivers meeting the optional warm-start capability may be used without harm.

5.10.1.6 Full Operational Status

Full operational status of the transceiver means that it has: (1) acquired bit timing (for NT), bit timing phase (for LT), and frame synchronization from the incoming signal from the other transceiver, (2) recognized the incoming superframe marker, and (3) fully converged both echo canceler and equalizer coefficients.

5.10.1.7 Total Deactivation

The word total deactivation is used in this TR to describe a process that includes the turn-off process as described here for this interface (see Section 5.10.1.8) and deactivation of the S/T interface as described in T1.605-1989.

5.10.1.8 Turn-off

The process by which a pair of fully operational transceivers transition to the RESET state.

5.10.1.9 Transparency

The word transparency is used in this TR to mean that B_1, B_2, or D channel (2B+D) bits received by the transceiver on the interface are passed to the TE at the NT and to the network at the LT. Likewise, when a transceiver is transparent, 2B+D bits sent to the transceiver at the LT from within the network or to the NT from the TE are transmitted on the interface. Conversely, when a transceiver is not transparent, 2B+D bits received on the interface are not passed along to the TE at the NT or to the network at the LT. Likewise, when a transceiver is not transparent, 2B+D bits from within the network at the LT or from the TE at the NT are not transmitted on the interface. Transparency applies separately to each transceiver. Conditions for transparency are discussed in Section 5.10.7.6.

5.10.2 Continuous Operation

(R) In normal operation, the DSL **shall** not be turned down and started up between customer uses of the customer's line. Once the DSL has been put in service, it **shall** operate continuously. regardless of whether the customer is using the D channel or one or more B channels for signaling or data or voice communication.

(R) The network **shall** restart the LT after the system has gone out of service due to a lightning hit, power hit, or momentary disruption of service. The NT may attempt to start-up (see Section 5.10.3.1) upon power-up, or upon a request for start-up from the customer terminal equipment.

(R) The NT **shall** enter the maintenance modes (i.e., Quiet Mode or Insertion Loss Measurement Test) upon a request for NT loop testing from the network and remain in the requested maintenance mode during the testing period. The NT **shall** exit the maintenance mode and enter RESET state after meeting conditions specified in 5.10. Both the NT and LT **shall** be capable of initiating the start-up process (see Sections 5.10.7.2 and 5.10.7.3) after the completion of metallic loop tests.

5.10.3 RESET

The RESET state consists of two sub-states: the RECEIVE RESET and FULL RESET states. In other sections of this TR, the term RESET is used to refer to the FULL RESET state.

RESET has no implications about the state of convergence of the equalizer or echo canceler coefficients of the transceiver. The RESET states are applicable to all transceivers.

For specific transceiver implementations, RESET states (or sub-states) may mean different and possibly multiple internal states.

5.10.3.1 FULL RESET

The FULL RESET state is one in which a transceiver has detected the loss of signal from the far-end and is not transmitting (sending signal to the loop).

(R) The FULL RESET state **shall** also be entered following power-up.

(R) Because the time for a cold start may be longer than desirable for normal operation (call origination), start-up **shall** be attempted upon NT power-up. After an unsuccessful start-up attempt, the NT transceiver may re-enter FULL RESET.

(R) While in FULL RESET, NTs **shall** initiate transmission only if responding to a new power off/on cycle or to a new request for start-up from the customer terminal equipment (TE). Under all other conditions, where the transceivers have been turned off, the NTs **shall** remain quiet, i.e., NTs **shall** not start transmitting any signal until they have received the TL signal (i.e., start-up tone) from the LT.

5.10.3.2 RECEIVE RESET

(R) The RECEIVE RESET state is a transient state in which an NT or an LT transceiver has detected the loss of signal from the far-end and is not transmitting (sending signal to the loop). In addition, the transceiver is not permitted to initiate the start-up sequence (send wake-up tone) but **shall** be capable of responding to the start-up sequence (detecting wake-up tone). Unless it responds to a wake-up tone, an NT or an LT transceiver **shall** remain in this state for at least 40 msec. after detecting the loss of received signal, as specified in 5.10.4 and 5.10.7.5, after which time, the transceiver **shall** enter the FULL RESET state.

5.10.4 Timers

(R) Timers **shall** be used to determine entry into the RESET states. Upon the occurrence of any of the following conditions:

(1) failure to complete start-up within 15 sec. (warm or cold start),

(2) loss of received signal for more than 480 msec.,

(3) loss of synchronization for more than 480 msec,

a transceiver **shall** respond as follows: Upon satisfying conditions (1) or (3), it **shall** cease transmission and then, upon the subsequent detection of the loss of received signal, the transceiver **shall** enter the RECEIVE RESET state. Its response time to a loss of signal (after conditions (1) or (3) have been satisfied) **shall** be such that it **shall** enter the RECEIVE RESET state and be capable of responding to the initiation of wake-up tone by the far-end transceiver within 40 msec. after the far end transceiver ceases transmission. Upon satisfying condition (2), the transceiver **shall** cease transmission and immediately enter the RECEIVE RESET state. As specified in 5.10.3, a transceiver **shall** remain in the RECEIVE RESET state for at least 40 msec., after which it **shall** enter the FULL RESET state.

For conditions (2) and (3), these requirements apply to transceivers after start-up, i.e., after superframe synchronization is achieved. (See T6 and T7 in Figures 5-11 and 5-12 for NT and LT transceivers, respectively).

In addition, an NT **shall** enter the FULL RESET state if signal is not received within 480 msec after it ceases the transmission of TN or SN1 if it is sent (see T2 to T3 in Figures 5-11 and 5-12).

5.10.5 Signals During Start-Up

(R) Figure 5-11 defines the signals produced by the transceivers during start-up. These signals apply during both types of start-up (cold start and warm start). During start-up, all signals at the interface **shall** consist of sequences of symbols of the shape defined by the pulse mask.
With the exception of the wake-up tones (TN and TL), the scrambler **shall** be used in the normal way in formulating the signals. For example, Figure 5-11 shows 1s for B and D channel bits and the overhead bits in the signals SN1. These 1s are scrambled before coding, producing random pulses in these positions at the interface.

Except where noted otherwise in Figure 5-11, all the pulse sequences, are framed and superframed in accordance with the normal frame structure shown in Figures 5-5 and 5-6, and all pulses represent scrambled bits except those in the synchronization word. The tones TN and TL are neither scrambled nor framed. The signals TN and TL are 10 kHz tones generated by repeating the following unscrambled symbol pattern:

$$+3\ +3\ +3\ +3\ -3\ -3\ -3\ -3$$

5.10.6 Line Rate During Start-Up

(R) During start-up, the network **shall** produce symbols at the nominal line rate within the tolerance specified in 5.3.

(R) The symbol rate from the NT **shall** be 80 kbaud ±100 ppm.

5.10.7 Start-Up Sequence

Figure 5-12 shows the sequence of signals at the interface that are generated by the transceivers. The transition points in the sequence are also defined in Figure 5-12.

5.10.7.1 Wake-Up

When transceivers are in the RESET state, either transceiver may initiate start-up by sending a tone as defined in Figure 5-11.

5.10.7.2 Start-up from Customer Equipment

(R) While the NT and LT are in the RESET state, a request for start-up from the customer terminal equipment **shall** result in the TN signal (wake-up tone) being sent from the NT toward the LT. The LT, upon receiving TN **shall** remain silent until detection of cessation of the signal from the NT. The rest of the sequence then follows as indicated in Figures 5-11 and 5-12. If the LT happens to try to start-up at the same time it may send a TL tone without conflict.
While in the RESET state, NTs **shall** initiate start-up if responding to a new power off/on cycle or to a new request for start-up from the customer terminal equipment. Under all other conditions, where the transceivers have been turned off, the NTs **shall** remain quiet, i.e., NTs **shall** not start transmitting any signal until they have received the TL signal (wake-up tone) from the LT.

5.10.7.3 Start-up from the LT

(R) While the NT and LT are in the RESET state, a request for start-up from the LT **shall** result in the TL signal being sent from the LT toward the NT. The NT, upon receiving TL **shall** respond with TN within 4 msec from the beginning of TL. The rest of the sequence then follows as indicated in Figures 5-11 and 5-12.

Note: The "dea" bit from the LT **shall** be set to 1 before start-up is initiated.

5.10.7.4 Progress Indicators

(R) In the NT-to-LT direction, the "act" bit remains set equal to 0 until the customer equipment is ready to transmit. The corresponding action at the T reference point in the customer equipment is receipt of the signal INFO3. To communicate this progress indication, act from the NT is set equal to 1. Assuming INFO3 occurs before T6 and T7, this progress indication **shall** not affect overhead symbols at the interface until T6 (Figure 5-12), when the NT overhead bits are allowed to be normal, and may not be detected by the LT until T7.

After event T7 (Figure 5-12) and after act = 1 is received from the NT, the LT sets the act bit equal to 1 to communicate readiness for layer 2 communications.

5.10.7.5 Turn-off Procedure

(R) All transceivers **shall** cease transmission following loss of received signal. There are different turn-off procedures for transceivers that have achieved full operational status than for transceivers that have not.

(O) The LT may take advantage of the capabilities of warm-start NTs by announcing turn-off. In announcing turn-off, the LT **shall** change dea from 1 to 0 and send dea = 0 in at least three consecutive superframes before ceasing transmission. It **shall** cease transmission before sending the dea bit in the superframe following the superframe in which dea = 0 is sent the last time. During the superframes with dea = 0, the NT has time to prepare for turn-off. Cold-start-only NTs may ignore the status of the dea bit.

(R) After the dea bit has prepared itself for turn-off, it **shall** upon detection of loss of signal from the LT, cease transmission, and enter the RECEIVE RESET state within 40 ms of the occurrence of the transition to no signal at its interface. As specified in 5.10.3, unless it responds to a TL signal from the LT, it **shall** not initiate the transmission of wake-up tone for a period of at least 40 ms after it ceases transmission, and then it **shall** enter the FULL RESET state.

(R) The LT, after announcing turn-off and ceasing transmission, **shall** enter the FULL RESET state upon detection of loss of received signal from the NT.

(R) Although NTs are not permitted to initiate turn-off, the LT **shall** respond to loss of signal as stated above. However, in this scenario, there is no stated means of taking advantage of warm-start capabilities.

5.10.7.6 Transparency

(R) Transparency of the transmission in both directions by the NT **shall** be provided after the NT achieves full operational status (T6), and both act = 1 from the LT and dea = 1. Full operation status of the NT means that the NT has: 1) acquired bit timing and frame synchronization from the incoming signal from the LT, 2) recognized the superframe marker from the LT, and 3) fully converged both its echo canceler and equalizer coefficients.

(R) Transparency of the transmission in both directions within the LT **shall** be provided when the LT achieves full operational status (T7), detects the presence of the superframe marker from the NT, and receives act = 1 from the NT. Full operational status of the LT means that the LT has: 1) acquired bit timing phase of the incoming signal from the NT, and frame synchronization, 2) recognized the superframe marker from the NT, and 3) fully converged both its echo canceler and equalizer coefficients.

(R) At the LT, transparency of the B and D channels **shall** occur at any time during either the first LT transmitted superframe with act=1 or during the last LT transmitted superframe with act=0. Transparency occurs at the transition from all 0s to "normal" in the B and D channels in SL3. For example, referring to Figure 5-8, suppose superframe A is the last transmit superframe with act=0, superframe B is the first transmit superframe with act=1, and superframes C and D continue with act=1. The transition to transparency may occur as early as the first bit of superframe A. The transition **shall** occur not later than the first bit of superframe C. This means that all B and D channel bits in superframes C and D **shall** be transmitted transparently, provided that conditions for transparency have been maintained.

At the LT, transparency of the B and D channels in the LT-to-network direction may occur at a different time than transparency in the LT-to-NT direction. However, in both directions the LT **shall** become transparent during the two transmit superframes A and B described in the example. The NT may not yet have achieved transparency during this interval.

(R) After both the LT and the NT achieve transparency in both directions, the act bits **shall** continue to reflect the state of readiness of the LT and the terminal equipment for layer 2 communication. The act bit in the LT-to-NT direction **shall** reflect the status of the network side of the interface, except during 2B+D loopback toward the LT. The act bit in the NT-to-LT direction **shall** reflect the status of the NT side of the interface. Whenever either end, for any reason, loses its readiness to communicate at layer 2 (e.g., the terminal is unplugged), that end **shall** set its transmitted act bit to zero. A change of status of this bit **shall** be repeated in at least three consecutive transmitted superframes.

Transparency required to perform loopbacks is independent of the state of the act bit.

5.10.7.7 Start-Up Time Requirements

(R) The LT and the NT **shall** complete the start-up process, including synchronization and training of equalizers to the point of meeting performance criteria within 15 sec. The 15-second cold-start time requirement is apportioned such that the NT is allowed 5 seconds and the LT is allowed 10 seconds.

(O) For transceivers that implement the warm-start option, the start-up process **shall** be completed within 300 ms. The 300-ms start-up time requirement is apportioned equally between the NT and the LT, 150 ms each.

Note: The 300 ms requirement applies to laboratory tests only. No 300-ms timer is involved in actual in-service loops.

As indicated in Figure 5-12, the start-up time requirements cover the time span from wake-up tone to T7, and do not include time for activation of customer terminal equipment. All start-up times apply only to the DSL, and do not apply to the entire customer access link where carrier systems may be involved.

The following description of a laboratory test of start-up time is intended only to clarify the start-up time requirements.

(R) The test **shall** be started by a wake-up tone (either TN or TL) and time recorded from the beginning of TN until event T7.

(O) It is desirable to separately record the accumulation of time components A + C and B + D as defined in Figure 5-12.

(R) The test **shall** be conducted on each of sixteen test loops. The test **shall** be conducted with an LT-NT pair on each test loop, first with the LT and NT as shown in Figure D-1, and then with the NT and LT inter-changed. Artificial crosstalk, power related metallic noise, and longitudinal noise **shall** be applied throughout the test. Furthermore:

(1) It is desirable to apply the interference to both ends of the test loop.

(2) It is desirable to conduct the test using clock sources with maximum frequency offsets.

(3) It is desirable to repeat the test a number of times in order to determine the degree of repeatability.

(O) For warm starts, the test **shall** begin from a RESET state that has been entered without loss of power following turn-off announcement as described in 5.10.7.5.

5.11 NT Maintenance Modes

The NT Quiet Mode (QM) functionality within an NT (or customer equipment containing the NT functionality) will assure that an NT will not attempt a start-up or will not initiate transmission during metallic loop tests conducted by the network.

The Insertion Loss Measurement Test (ILMT) will cause a known test signal to be generated by an NT. This test will be used in network measurements of DSL transmission characteristics and may provide the ability to determine, from a single-ended test of the metallic loop, if the loop can support DSL transmission.
Figure 5-13, NT Loop Testing States, illustrates the various NT states associated with both the NT Quiet Mode and the Insertion Loss Measurement Test.

5.11.1 NT Quiet Mode

The NT Quiet Mode **shall** be implemented as follows:

(R) The NT **shall** unconditionally enter the Quiet Mode upon receipt of 6 consecutive pulses in the trigger signal (see 5.10.3, 5.10.4, and 5.10.5). Once triggered, the functions **shall** latch until either timeout or turnoff.

(R) While in Quiet Mode, the NT **shall** cease all transmission, and not attempt start-up.

(R) The NT Quiet Mode duration **shall** be 75 seconds. If no trigger signal is received to change the NT state during the 75 second Quiet Mode duration, the NT **shall** exit the maintenance mode and enter the RESET state. Upon exiting the maintenance mode and subsequently entering the RESET state, the NT and the LT **shall** be responsible for the start-up process described in 5.10.7.2 and 5.10.7.3.

(R) A receipt of 6 consecutive pulses in the trigger signal during Quiet Mode **shall** cause the NT to return to the start of the Quiet Mode state (The Quiet Mode would then continue for another 75 seconds until either timeout or receipt of a new trigger signal that would alter the NT state).

(R) A receipt of 8 consecutive pulses in the trigger signal during Quiet Mode **shall** cause the NT to enter the Insertion Loss Measurement Test state.

(R) A receipt of 10 consecutive pulses in the trigger signal during Quiet Mode **shall** cause the NT to exit the maintenance mode.

(R) If the NT receives 1 through 5, 7, 9, or greater than 10 consecutive pulses in the trigger signal then the state change command is not valid and no action is taken by the NT.

5.11.2 Insertion Loss Measurement Test

The Insertion Loss Measurement Test implementation **shall** be as follows:

(R) The receipt by the NT of 8 consecutive pulses in the trigger signal **shall** unconditionally initiate the Insertion Loss Measurement Test. Once triggered, the function **shall** latch until either timeout or turnoff. The NT **shall** not attempt start-up during the Insertion Loss Measurement Test.

(R) While in the Insertion Loss Measurement Test state, the NT **shall** generate a scrambled, framed, 2B1Q signal. SN1 and SN2 are examples of scrambled, framed, 2B1Q signals suitable for the Insertion Loss Measurement Test signal.

(R) The Insertion Loss Measurement Test duration **shall** be 75 seconds. Upon exiting the maintenance mode and subsequently entering the RESET state, the NT and the LT **shall** be responsible for operation as described in 5.10.7.2 and 5.10.7.3.

(R) A receipt of 8 consecutive pulses in the trigger signal during the Insertion Loss Measurement Test duration **shall** cause the NT to return to the start of the Insertion Loss Measurement (The ILMT would then continue for 75 seconds until timeout or receipt of a new trigger signal to alter the NT state).

(R) A receipt of 6 consecutive pulses in the trigger signal during Insertion Loss Measurement **shall** cause the NT to enter the Quiet Mode state.

(R) A receipt of 10 consecutive pulses in the trigger signal during Insertion Loss Measurement Test **shall** cause the NT to exit the maintenance mode.

(R) If the NT receives 1 through 5, 7, 9, or greater than 10 consecutive pulses in the trigger signal then the state change command is not valid and no action is taken by the NT.

Figure 5-13 illustrates the various NT states associated with both the NT Quiet Mode and the Insertion Loss Measurement Test.

5.11.3 NT Quiet Mode and Insertion Loss Measurement Test Trigger Signal

The NT **shall** be capable of detecting the following two types of signals:

(R) The NT **shall** respond to either (1) dc signaling that begins with a steady current flow (start interval) followed by 6, 8, or 10 pulses sent as breaks in the current (see Section 5.11.4) and ends with steady dc current flow (stop interval), or (2) ac signaling that begins with no current flow (start interval, less than 200 μA dc) followed by 6, 8, or 10 half cycles of a 2 to 3 Hz sine wave, and ends with no current flow (stop interval). When receiving the ac signaling, the NT **shall** count each half cycle of the sine wave as one pulse.

(R) A valid test trigger signal **shall** consist of a valid start interval followed by either 6, 8, or 10 consecutive pulses followed by a valid stop interval. Unless an entire trigger sequence consisting of start interval, pulses, and stop interval is received, the NT **shall** take no action.

(O) A stop interval may be followed by a start interval without any intervening breaks. Signals on the loop before the start interval or after the stop interval **shall** not affect the NT trigger detection function.

(R) The start and stop interval **shall** be $\geq$ 500ms. The NT **shall** be capable of detecting and validating the trigger signal and entering into the desired state required by the number of pulses transmitted.

(R) A request for the same or a new state **shall** occur no sooner than 1 second after the beginning of the preceding stop interval. On receipt of a valid signal the NT **shall** transition from one state to the requested state within 500 ms.

(R) The pulse detector in the NT **shall** be implemented so that there is no aliasing for pulse rates up to 64 pulses per second.

5.11.4 dc Signaling Format

(R) The dc signal **shall** begin with a steady current flow with pulses sent as breaks in the current. These pulses **shall**: (1) be applied to the NT by test equipment in the LT at a pulse speed of 4 to 8 pulses per second, (2) have a 40 to 60 percent break, (3) have source voltage of 43.5 volts to 56 volts, and (4) have source resistance of 400 ohms to 3600 ohms (includes test system, test trunk, loop, and margin resistance).

5.11.5 Low Frequency ac Signaling Format

(R) The ac signal **shall** consist of 6, 8, or 10 half cycles of 2 to 3 Hz sine wave. This sine wave **shall** (1) be applied to the NT by test equipment at the LT end, (2) have peak voltage between 60 and 62 volts, and (3) have a source resistance between 900 ohms and 4500 ohms (ac source, test system, test trunk, loop, and margin resistance).